1.3 Average Velocity

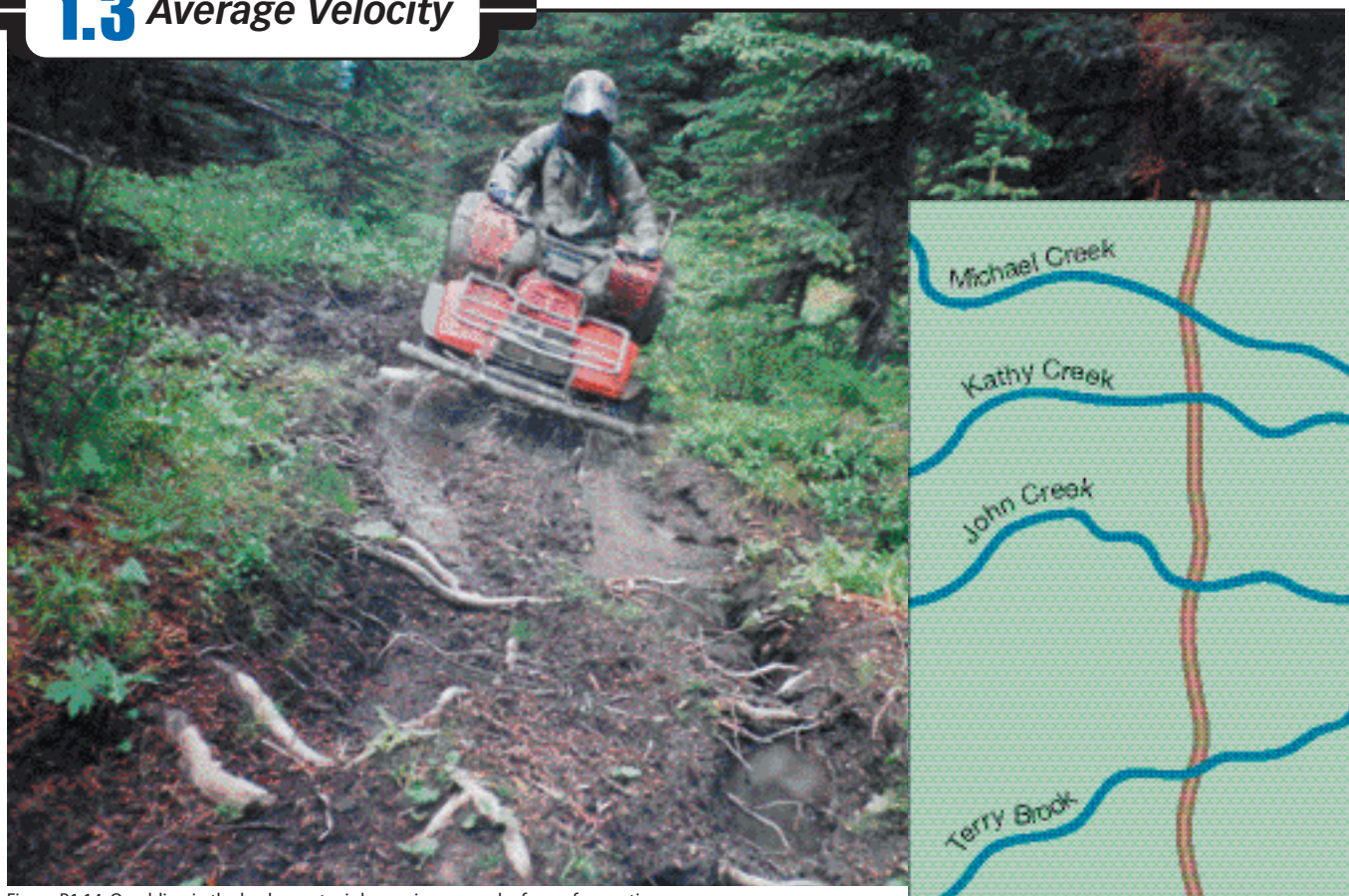

Figure B1.14: Quadding in the back country is becoming a popular form of recreation.

Exploring wild and remote places is a pastime enjoyed by many people. For some people, the mode of travel is self-propelled: cross-country skiing, hiking, canoeing, mountain biking, snowshoeing, and so on. Others prefer to travel by horseback, snowmobile, quad, or motorboat. In all cases, if the idea is to reach a remote location, skills in reading a map are essential. Figure B1.15 shows a rough trail that cuts through an area of the Rocky Mountains. The main base camp is the origin—the place where all the day trips originate. Some people call it the reference point.

Figure B1.15 is referenced throughout this lesson. To avoid flipping back and forth, you can obtain the handout "Figure B1.15: Rocky Mountain Adventure" from the Science 20 Textbook CD.

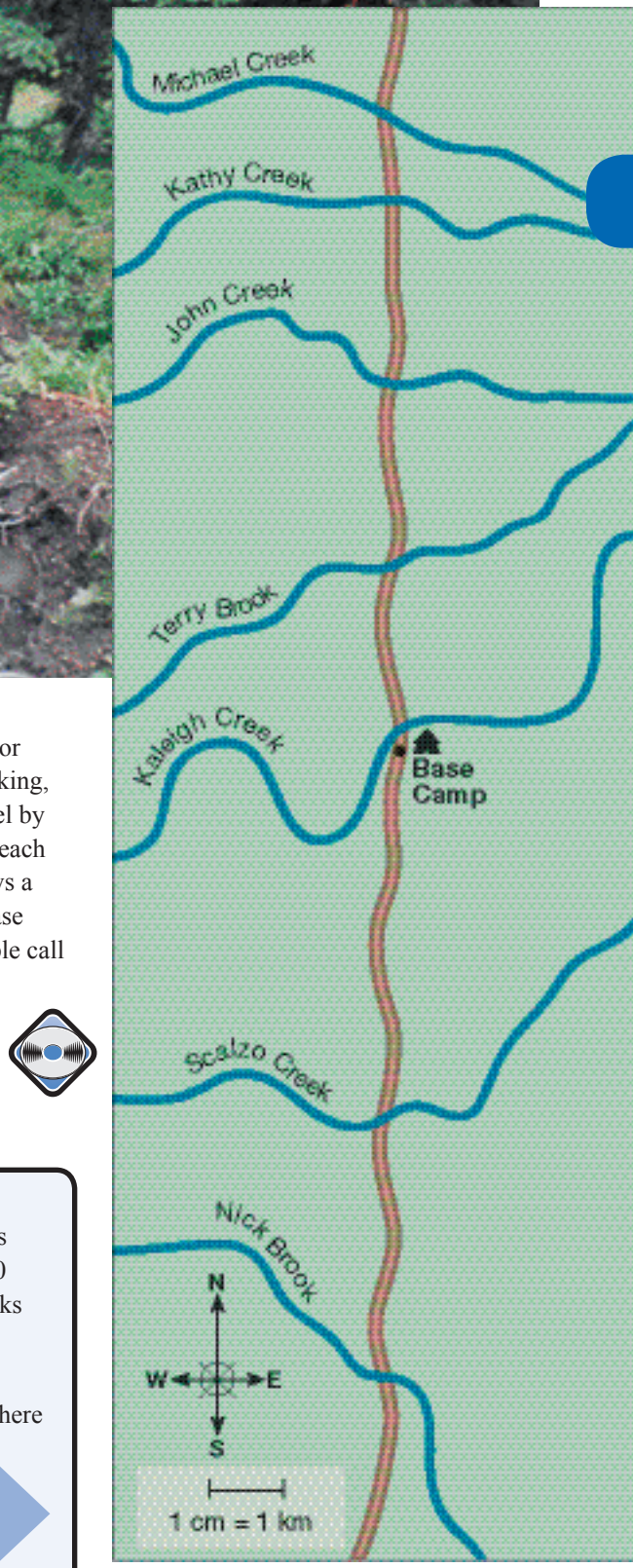

Figure B1.15: It's always important to have a map when exploring unfamiliar territory.

Example Problem 1.5

It's about 9:00 a.m., and Raj has just gotten out of his sleeping bag. He's surprised to learn that two of his companions, Melissa and Usha, left 2.0 h ago to explore a stream that crosses the trail somewhere. When Raj asks Harvey, another member of this group, where Melissa and Usha went, Harvey replies, "They're about 5 km from here."

a. Use a ruler and the scale at the bottom of Figure B1.15 to identify where Melissa and Usha could be.

b. If Raj and Harvey want to join Melissa and Usha, what information other than the 5-km distance will they need?

continued on next page

Solution

a. Since the scale on the map is 1.0 cm = 1.0 km and Melissa and Usha are 5.0 km from base camp, measure 5.0 cm from base camp on the map to determine their location. According to the map, Melissa and Usha are either at John Creek or Scalzo Creek.

b. In addition to the 5 km, Raj and Harvey will need to know the direction.

Position

If you want to find a location using a map, you will need more than just the distance. It is most helpful to also know the direction of the location relative to the starting place or reference point. You'll need **position**. Position is the distance and direction of a location relative to a reference point. So, if Melissa and Usha are at the John Creek crossing, their position is 5.0 km north of base camp. If they are at Scalzo Creek trail crossing, however, their position is 5.0 km south of base camp. Notice that the base camp is the reference point.

- position: a vector quantity describing the location of a point relative to a reference point
- vector: a quantity consisting of magnitude and direction

Since each of the position measurements includes a direction, position is called a **vector**. A vector is a quantity with magnitude and direction. To keep from mixing up distance and position, the symbol for position includes an arrow overtop the variable. This is a shorthand way to say that this quantity includes direction.

Base Camp to . . .	Distance	Position
John Creek	d = 5.0 km	$\vec{d}$ = 5.0 km[N]
Scalzo Creek	d = 5.0 km	$\vec{d}$ = 5.0 km[S]

Notice that the distances from the base camp to John Creek and to Scalzo Creek are the same, but the positions are not. So, if adventurers leave base camp and walk along the trail to one of the creek crossings, there are only two choices for direction: north and south. In situations like this, it is often convenient to use a **sign convention**, letting positive represent one direction and negative represent the opposite direction.

- sign convention: an agreement about which direction is positive and which is negative

This is how the positions of John Creek and Scalzo Creek crossings could be expressed with a sign convention.

Sign Convention	Position from Base Camp to . . .	
	John Creek	Scalzo Creek
N + / S -	$\vec{d}$ = 5.0 km[N] $\vec{d}$ = +5.0 km	$\vec{d}$ = 5.0 km[S] $\vec{d}$ = −5.0 km

Note that the sign convention is written beside the displacement values. Also, notice that the symbol for north is replaced by a positive sign and the symbol for south is replaced by a negative sign.

Practice

14. Use a ruler and Figure B1.15 to determine the position of each creek crossing given. Consider the base camp to be the reference point. In each case, describe the direction in terms of north or south and using sign convention, where north is positive and south is negative.
    a. Terry Brook crossing
    b. Kaleigh Creek crossing
    c. Nick Brook crossing

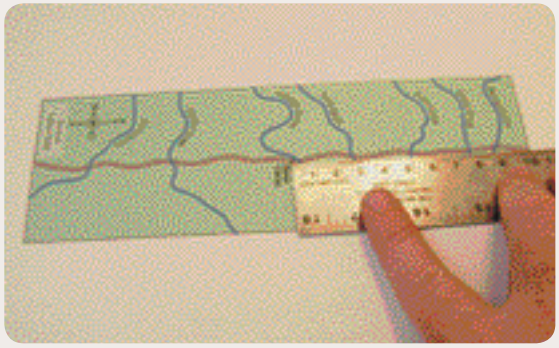

Figure B1.16: You can see interesting things in nature by simply hiking down a trail in the wilderness.

Displacement

To compare the positions of two locations in which neither is the reference point, you need to use **displacement**. The symbol for displacement is $\Delta\vec{d}$, where the Greek letter *delta* (D) is short for "change in." So, when you see $\Delta\vec{d}$, read it as "displacement," "change in position," or "delta dee." As you'll see in Example Problem 1.6, displacement can be found using position values or by measuring directly from the map.

displacement: a vector quantity describing the length and direction in a straight line from the starting position to the final position

Example Problem 1.6

Determine the displacement from the Michael Creek crossing to the Nick Brook crossing.

Solution

The Nick Brook crossing is 17.2 cm from the Michael Creek crossing. Therefore, the displacement from the Michael Creek crossing to the Nick Brook crossing is $\Delta\vec{d} = 17.2 \text{ km[S]}$ or -17.2 km.

Practice

15. Use a ruler and Figure B1.15 to determine the displacement of each of the following. In each case, describe the direction in terms of north and south and using sign convention, where north is positive and south is negative.
    a. from the Scalzo Creek crossing to the Terry Brook crossing
    b. from the Nick Brook crossing to the John Creek crossing
    c. from the Kathy Creek crossing to the Terry Brook crossing
    d. a day-long trip starting from base camp, to the Michael Creek crossing, and back to the Terry Brook crossing
16. Compare your answer to question 15.d. to your answer to question 14.a. Did the middle portion of the trip to the Michael Creek crossing make any difference to the final answer? What can you conclude?

Average Velocity

If you want to know how fast an object is moving, the average speed of the object is useful. But average speed does not reveal anything about the direction of motion. The term that describes both the magnitude of how fast an object is moving and the direction it is moving is called **average velocity**. The words *speed* and *velocity* are used interchangeably in everyday speech; but as you will see in the following table, they are significantly different.

average velocity: a vector quantity describing the change in position over a specified time

Scalars	
Scalar Quantities	**Scalar Equation**
distance, Dd time, Dt average speed, v	$\text{average speed} = \frac{\text{distance}}{\text{time}}$ $v = \frac{\Delta d}{\Delta t}$
Vectors	
Vector Quantities	**Vector Equation**
displacement, $\Delta\vec{d}$ average velocity, $\vec{v}$	$\text{average velocity} = \frac{\text{displacement}}{\text{time}}$ $\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$

Note how the symbol for velocity has the same reminder for you as the symbol for displacement; it has a vector symbol (Æ) overtop because it includes direction.

Example Problem 1.7

If Raj travels along the trail from the John Creek crossing to the Nick Brook crossing in 3.5 h, what is Raj's average velocity for this trip in kilometres per hour?

Solution

On the map, the Nick Brook crossing is 13.5 cm from the John Creek crossing.

$\Delta\vec{d} = 13.5 \text{ km[S]}$
$= -13.5 \text{ km}$

$\Delta t = 3.5 \text{ h}$

$\vec{v} = ?$

$\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$
$= \frac{-13.5 \text{ km}}{3.5 \text{ h}}$
$= -3.9 \text{ km/h}$

Raj's average velocity for this trip is 3.9 km/h[S].

Example Problem 1.8

Melissa leaves the Nick Brook crossing and travels along the trail at 2.50 m/s[N] for 1.25 h.

a. Calculate Melissa's displacement from the Nick Brook crossing.

b. Use the map and a ruler to determine where she likely stopped.

Solution

a. $\vec{v} = 2.50 \text{ m/s[N]}$

$= +2.50 \frac{\cancel{\text{m}}}{\cancel{\text{s}}} \times \frac{1 \text{ km}}{1000 \cancel{\text{m}}} \times \frac{3600 \cancel{\text{s}}}{1 \text{ h}}$

$= +9.00 \text{ km/h}$

$\Delta t = 1.25 \text{ h}$

$\Delta \vec{d} = ?$

$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$

$\Delta \vec{d} = \vec{v} \Delta t$

$= (+9.00 \text{ km/h})(1.25 \text{ h})$

$= +11.3 \text{ km}$

Melissa is 11.3 km[N] from the Nick Brook crossing.

b. In Figure B1.15, 11.3 km = 11.3 cm. Therefore, Melissa stopped slightly north of the Terry Brook crossing.

Example Problem 1.9

Suppose Usha and Melissa start a day-long trip along the trail by travelling from the Kathy Creek crossing to the Nick Brook crossing. This leg of the trip takes 2.25 h. They stay at the Nick Brook crossing for 1.75 h before deciding to head to the Michael Creek crossing. The entire journey takes 3.00 h.

a. Determine Usha and Melissa's average speed for the entire trip.

b. Determine Usha and Melissa's average velocity for the entire day trip.

c. Account for the different values obtained for average speed and average velocity.

Solution

a. $\Delta d = 16.0 \text{ km} + 17.2 \text{ km}$

$= 33.2 \text{ km}$

$\Delta t = 2.25 \text{ h} + 1.75 \text{ h} + 3.00 \text{ h}$

$= 7.00 \text{ h}$

$v = ?$

$v = \frac{\Delta d}{\Delta t}$

$= \frac{33.2 \text{ km}}{7.00 \text{ h}}$

$= 4.74 \text{ km/h}$

Usha and Melissa's average speed for the entire trip was 4.74 km/h.

b. $\Delta \vec{d} = 16.0 \text{ km[S]} + 17.2 \text{ km[N]}$

$= (-16.0 \text{ km}) + (+17.3 \text{ km})$

$= +1.2 \text{ km}$

$\Delta t = 2.25 \text{ h} + 1.75 \text{ h} + 3.00 \text{ h}$

$= 7.00 \text{ h}$

$\vec{v} = ?$

$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$

$= \frac{+1.2 \text{ km}}{7.00 \text{ h}}$

$= +0.17 \text{ km/h}$

The average velocity of the trip was 0.17 km/h[N].

c. Distance is used to calculate the scalar quantity average speed. Displacement is used to calculate the vector quantity average velocity. Combining negative and positive values produced a smaller displacement; this resulted in a lower average velocity value.

Look at the differences in the solutions to parts a. and b. in Example Problem 1.9. The vector approach, shown in part b., has very different outcomes than the scalar solution in part a. If you keep in mind that displacement is simply the change in position between the starting point and the ending point, the results begin to make sense. Since the displacement of the Michael Creek crossing is only 1.2 km[N] from the Kathy Creek crossing, it makes sense that the average velocity is such a small value since the elapsed time is 7.00 h. The value 1.2 km[N] is called the **resultant displacement**—it is the result of adding individual displacements from each leg of a journey.

resultant displacement: the vector sum of individual displacements

Finding Resultant Displacement with Scale Diagrams

In Example Problem 1.9 you needed to determine the resultant displacement by finding the change in position between two locations. Another approach is to draw a scale diagram. This method represents each of the position vectors with an arrow. As shown in Figure B1.17, the length of the arrow represents the magnitude—the number of kilometres—and the direction the arrow points represents the direction of motion.

The method of finding the displacement for the entire journey involves correctly drawing one vector to scale; then at the head of the first vector, start the next scale drawing—the tail—of the second vector. For this reason, it is sometimes referred to as the **head-to-tail method**.

head-to-tail method: a method where the tail of a succeeding vector arrow begins at the head of the preceding vector arrow

The resultant displacement is then represented by a third arrow drawn from the tail of the first vector (starting point of motion) to the head of the second vector (ending point of the motion). As shown in Figure B1.18, the resultant displacement vector is determined by using the direction the arrow points and the scale. Remember this interpretation of displacement as you try the next set of Practice questions.

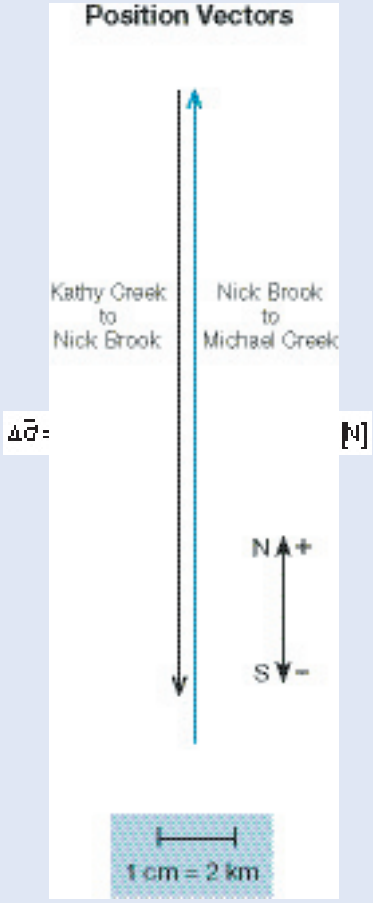

Figure B1.17: It is very important to draw your position vectors correctly to scale.

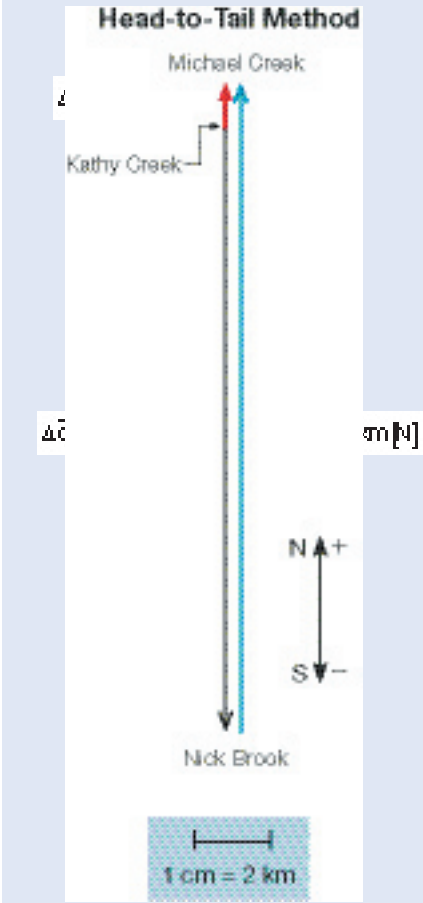

Figure B1.18: By correctly drawing the position vectors, you can find the resultant displacment.

Practice

Use a ruler and Figure B1.15 to answer questions 17 and 18.

17. Because the fish weren't biting at Scalzo Creek, Raj and Harvey travelled north for 2.5 h to try their luck at John Creek. The fishing was good at John Creek, so they stayed there for 3.0 h before deciding to return to base camp. The trip to base camp took another 1.5 h.
    a. Determine the displacement from the Scalzo Creek crossing to the John Creek crossing and from the John Creek crossing to base camp.
    b. Use the head-to-tail method to determine the resultant displacement.
    c. Verify your answer for question 17.b. by determining the resultant displacement using sign convention.
    d. Calculate the average speed for the entire journey.
    e. Calculate the average velocity for the entire journey.
18. Melissa and Usha leave Terry Brook with an average velocity of 4.0 km/h[S]. If they travel with this velocity for 2.75 h, calculate their displacement from Terry Brook. Where did Melissa and Usha end up?

DID YOU KNOW?

The Wilderness Is Accessible!

If you had to travel 40 km in one day through wilderness terrain, what would be your preferred mode of transportation? Assuming that you have necessary training, you might choose either a quad or snowmobile, depending on the time of year.

How would people without the use of their legs answer this question? You might be surprised to know that they would likely choose a quad or a snowmobile too.

As a member of the Canadian Paraplegic Association, Rick Lenglet combines his first-hand experience with his knowledge of these vehicles to make modifications that enable people with disabilities to enjoy outdoor pursuits. As Rick demonstrates in the following photos, switching from a wheelchair to a quad is not a big deal at all.

Rick explains: "Quads that are fully automatic, require minimal modifications . . . On my snowmobile I just had to add a few straps and some foot holds so that my legs stay close to the machine . . . People are always amazed at how inexpensive these modifications can sometimes be."

One of Rick's recent projects is a horse-drawn cart he designed to fit his wheelchair. When it comes to enjoying the land on his acreage just west of Edmonton, this has become his favourite mode of transportation.

1.3 Summary

Position is the distance and direction of a location relative to a reference point. When describing a change in position, displacement is used. Both of these quantities are called vectors because they both have magnitude and direction. Another vector quantity is average velocity, which is determined by dividing the displacement by the elapsed time.

$$\text{average velocity} = \frac{\text{displacement}}{\text{elapsed time}}$$

$$\vec{v} = \frac{\Delta \vec{d}}{\Delta t}$$

Vectors, such as displacement, can be determined using a scale diagram and the head-to-tail method. The resultant displacement is the sum of the individual displacements.

1.3 Questions

Knowledge

1. Define each term, and provide an example.

- **a.** position
- **b.** displacement
- **c.** vector
- **d.** sign convention
- **e.** average velocity

Applying Concepts

Figure B1.19 shows some of the details of a snowmobile outing. The reference point is the place where the snowmobilers park their trucks to begin their outing. They can start by travelling east—the positive direction—or by travelling west—the negative direction.

Use this information to answer questions 2 to 5.

2. Determine the position of each of the following locations from the reference point. Describe the direction in terms of east and west and by using the sign convention.

- **a.** Bird Creek
- **b.** Elk Creek
- **c.** the pipeline corridor
- **d.** the start of Lake Trail

3. Terry leaves the reference point and takes 0.75 h to travel to Bird Creek. Terry rests for 0.25 h at Bird Creek before travelling 2.00 h to Elk Creek.

- **a.** Determine Terry's resultant displacement by adding individual displacements and by using a ruler to complete the head-to-tail method.
- **b.** Calculate Terry's average speed and average velocity.

4. Monica leaves the place where the trail meets the Pipeline Corridor and travels for 1.75 h to Elk Creek. She rests at Elk Creek for 0.75 h, then travels 2.5 h to Bird Creek.

- **a.** Determine Monica's resultant displacement by adding individual displacements and by using a ruler to complete the head-to-tail method.
- **b.** Calculate Monica's average speed and average velocity for the entire trip.

5. One snowmobiler left the reference point and travelled 24.0 km/h east for 30.0 min.

- **a.** Calculate the snowmobiler's displacement after 30.0 min.
- **b.** Determine the likely location of the snowmobiler after 30.0 min.

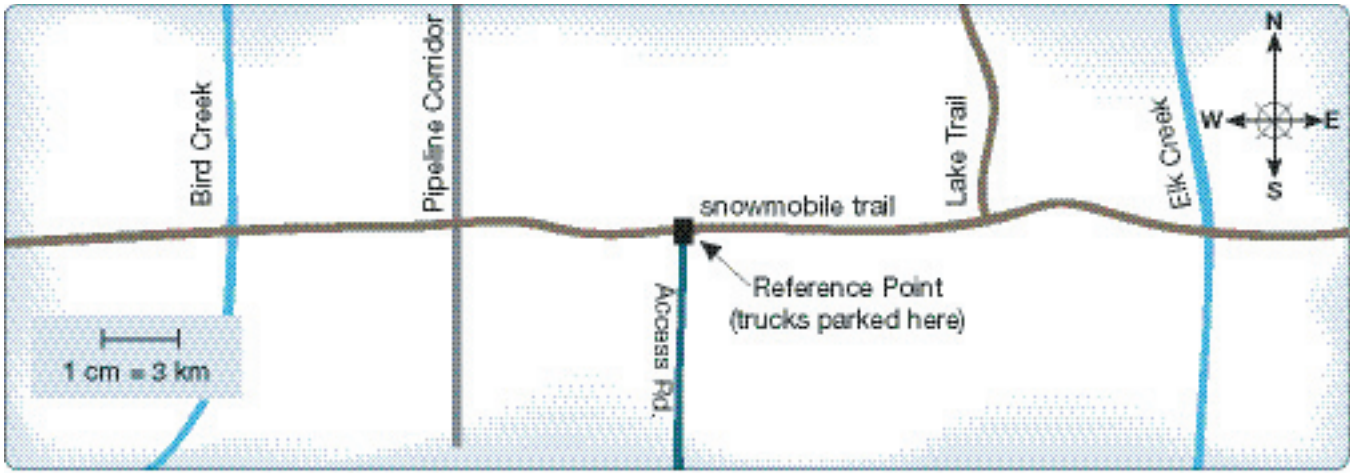

Figure B1.19: Snowmobilers must travel either east or west of the reference point to get to their desired trails.